INTERSTATE 405 Corridor Program
Congestion Relief & Bus Rapid Transit Projects

APPENDIX O1-D

STORMWATER DESIGN DECISION, USE OF "OFF-SITE INFLOW AREA OPTION" TO REDUCE FLOW CONTROL FACILITY SIZES

I-405, SR520 to SR522 Stage 1 (Kirkland Stage 1)

Draft RFP
March 22, 2005

Washington State Department of Transportation

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Stormwater Design Decision
Use of "Off-site Inflow Area Option"
To Reduce Flow Control Facility Sizes

March 3, 2005

Washington State
Department of Transportation

Introduction

The purpose of this paper is to formalize and document the decision to use the "Off-site Inflow Area Option" (as provided in Chapter 4 of the Highway Runoff Manual) to improve runoff attenuation characteristics in the project flow control facilities, thus reducing detention volumes.

Background

Previously accepted design criteria for the Kirkland Nickel project assumes a conservative approach for flow control facility sizing. Detention sizes were calculated based on new impervious area only within the respective threshold discharge area, neglecting any additional on-site or off-site flows. This method provides the largest detention volumes because it assumes flow control target discharge rates based on predeveloped forested conditions for the defined subject mitigation area.

WSDOT Highway Runoff Manual, Section 4-3.6 Hydrologic Analysis Methods for Flow Control and Runoff Treatment Facility Design provides for the inclusion of off-site runoff for modeling of flow control facilities when it is not practical to separate off-site and on-site flows. The Off-site Inflow Area Option accounts for the additional off-site inflow "in a way that meets the overall intent of mitigating the effects of increased runoff generated from the project site".

Design criteria outlined in the HRM for the Off-site Inflow Area Option include the following:

- Control of off-site inflow: With this option, flow control is provided for runoff from an upslope area outside the project limits, if the existing 100-year peak flow rate from the off-site inflow area is less than 50% of the 100-year peak flow rate of the on-site mitigation area (for post-developed conditions, without flow control) for the TDA. The control of off-site runoff must be designed to achieve the following:
    - Any existing contribution of flows to a wetland must be maintained.
    - Off-site flows that are naturally attenuated by the TDA under predeveloped conditions should remain attenuated, either by natural means or by implementing additional on-site flow control measures, so the a peak flows do not increase.

The Highway Runoff Manual defines "off-site" as any area lying upstream of the project site that drains onto the site, and/or any area lying downstream of the site to which the site drains. This definition may include areas of highway pavement lying just outside of the project limits, yet still within the WSDOT right-of-way, or areas that are completely outside of the WSDOT right-of-way. WSDOT strongly prefers to separate off-site and on-site runoff because of its inability to control stormwater discharges generated outside of its right-of-

way. It is highly preferable to treat (for flow control and water quality) only stormwater runoff that is generated within the right-of-way area.

Threshold discharge area TDA-C has been targetted for this analysis due to the high cost of detention vault storage. Additionally, the subject area is situated in a portion of the freeway corridor where separation of off-site flows (within the right-of-way) is not practical. In this case, acceptance of additional existing freeway pavement to be included for design of the associated flow control facilities is considered beneficial because it maintains the existing flow patterns within the basin, meets the intended downstream levels of flow control protection, and reduces detention vault sizing and related costs.

I-405 design team has proposed flow control designs for TDA-C in two separate facilities. An open pond is proposed at approximate milepost 19.0, and a large closed detention vault to be constructed at approximate milepost 19.4. Preliminary sizing for both of these facilities was based on flow control modeling for equivalent areas of new pavement only, assuming forested predeveloped condition. By using the Off-site Inflow Area Option, flow control may be recalculated to provide a more efficient and cost effective design that meets the intent of the flow control standards.

Summary

Figure 1 illustrates the contributing drainage basins for TDA-C, including on-site mitigation areas, and the targeted "off-site" I-405 mainline pavement area. The contributing off-site inflow area includes a potentially large portion of the freeway, such that the 100-year peak flow rate would be greater than 50% of the 100-year peak flow rate of the on-site mitigation area. Adjustments will be needed for the proposed on-site conveyance system in order to capture the appropriate contributing area.

For this document, off-site inflow area was determined only for the vault portion of TDA-C (not including the pond portion). However, it is assumed that by acceptance of this document, the Off-site Inflow Area Option may be used for all threshold discharge areas in the Kirkland segment where conditions allow. A process for determining the off-site inflow area is provided as follows:

- Step 1 – Determine 100-year peak flow for on-site mitigation area (for post-developed conditions without flow control).
- Step 2 – Determine maximum off-site inflow area that will fit within constraints of design criteria (i.e., 100-yr peak flow for off-site area is less than 50% of 100-year peak flow from on-site mitigation area, assuming off-site inflow area is 100% impervious freeway pavement).
- Step 3 – Adjust proposed conveyance system to capture appropriate catchment area and size the flow control vault based on the adjusted basin (assuming equivalent on-

site mitigation area modeled to forested predevoped conditions, and off-site inflow areas modeled to existing predeveloped conditions).

Based on the steps outlined above, a new vault volume was calculated with the MGS Flood software to be approximately 2.17-acre feet. This is a reduction of approximately 2.43-acre feet (or about 53%) in storage volume from the previously calculated vault.

Decision Basis

Proceeding with the On-site Inflow Area Option for this project is based on the following:

Overall benefit to the environment:
Use of On-site Inflow Area methodology meets the overall intent of mitigating the effects of increased runoff generated from the project site. Use of this method does not reduce the effectiveness or lessen flow control mitigation efforts to protect the downstream environment. Similarly, runoff treatment for water quality will not be affected for freeway runoff (ecology embankments will remain). A stipulation of this method includes that when runoff treatment for water quality is provided in connection with the flow control system, the water quality BMP will be sized to accommodate and treat the additional volume.

Significant decrease in project costs:
By utilizing efficiencies of flow characteristics from the larger basin, detention vault size would be reduced by approximately 50%. Vault size reduction of this magnitude would reduce capital construction cost by approximately $1,000,000.

Decision Summary

Use of the Off-site Inflow Area Option will allow design teams to meet flow control standards, maintain existing basin flow characteristics, and reduce detention facility sizes and associated costs. Where stormwater quality treatment and flow control are combined in the facility, the design team shall provide water quality treatment for the full contributing area.

Concurring Approvals:

Alex Nguyen, WSDOT
Headquarters Hydraulics Div.

3/10/05
Date

Alan Black, I-405 Design Team

3/10/05
Date

ATTACHMENTS:

FIGURE 1 TDA-C DRAINAGE MAP – OFF-SITE INFLOW AREA OPTION

TDA-C VAULT SIZING CALCULATIONS

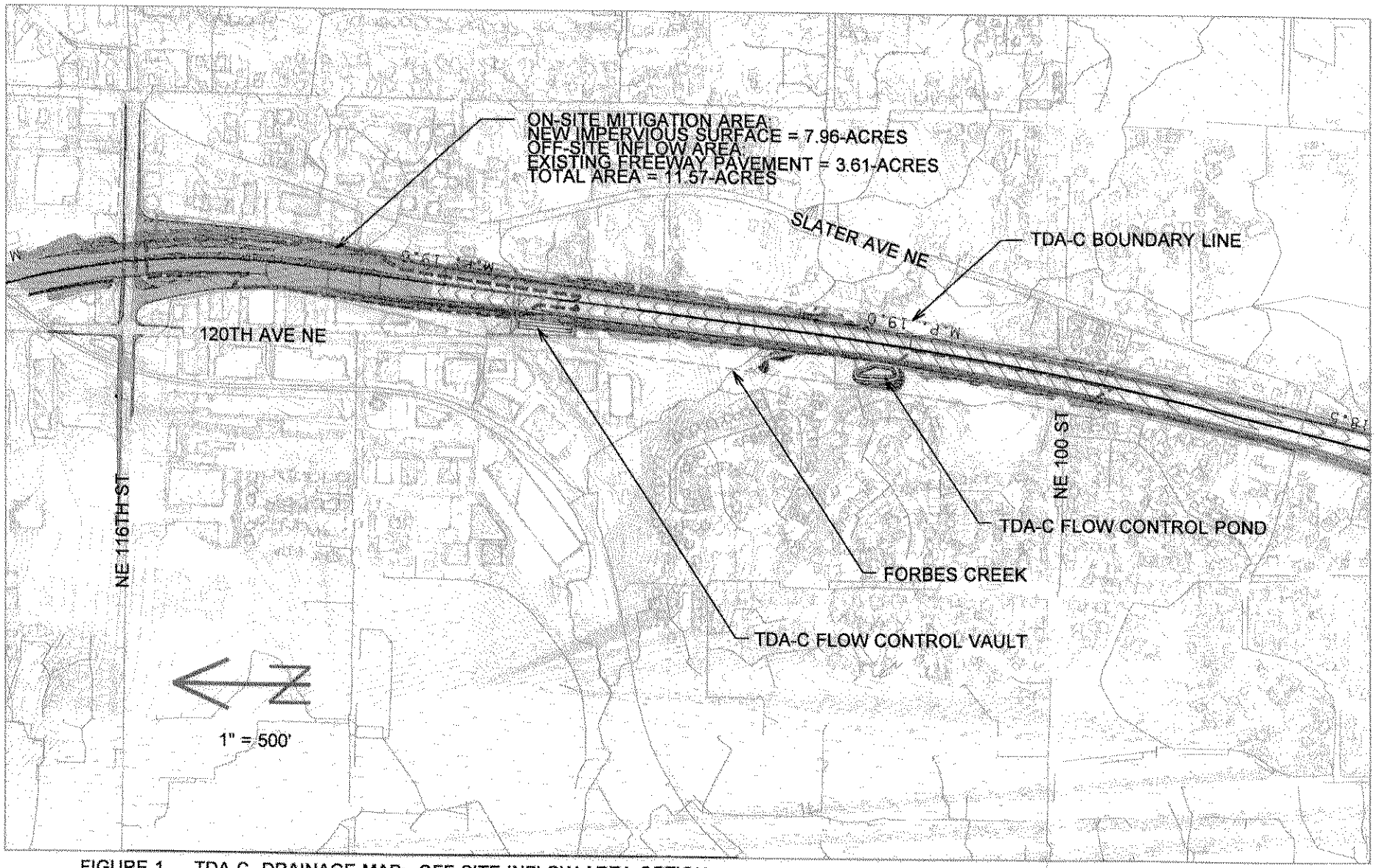

FIGURE 1 TDA-C DRAINAGE MAP; OFF-SITE INFLOW AREA OPTION

TDA-C VAULT SIZING CALCULATIONS

Use Off-site Inflow Area Option to size detention vault in Threshold Discharge Area C

Total Mitigation Area (new impervious surface) in TDA-C

Stage 1 =	6.06-acres
Stage 2 =	3.56-acres
Total =	**9.62-acres**

Mitigation Area treated in TDA-C flow control pond facility = 1.66-acres

Mitigation Area to be treated in flow control vault:

9.62-acres - 1.66-acres = **7.96-acres**

Per Highway Runoff Manual, Section 4-3:

Off-site Inflow Area Option

"With this option, flow control is provided for runoff from an upslope area outside the project limits, if the existing 100-year peak flow rate of the off-site mitigation area is less than 50% of the 100-year peak flow rate of the on-site mitigation area (for post-developed conditions, without flow control) for the TDA".

Freeway conveyance system may be adjusted to regulate the pavement capture area. Determine maximum capture area of freeway pavement:

Step 1:
Calclulate 100-yr peak rate from on-site mitigation area = 7.96-acres

Q100 (on-site) = 4.824-cfs

½ Q100 (on-site) = 2.41-cfs

(See attached file: TDA-C FLOWRATES2.fld)

Step 2:
Calculate maximum area of off-site inflow area (assume 100% impervious surface):

3.9-acres impervious freeway surface will generate a 100-yr peak flow rate

Q100 (off-site) = 2.36-cfs < ½ Q100 (on-site) = 2.41-cfs

(See attached file: TDA-C OFF-SITE FLOWRATES 2.fld)

Step 3:
Calculate detention volume using adjusted "off-site inflow area option" basin:

Maximum freeway pavement area:

Impervious surface < 7.96-acres + 3.9-acres = 11.86-acres

Adjust TDA-C proposed freeway conveyance system to collect and convey pavement area meeting these calculated area parameters.

Adjusted captured pavement area (see Figure 1)

On-site Mitigation Area = 7.96-acres
Off-site Inflow Area = 3.61-acres

Total Area routed to vault = 11.57-ac

Vault sized with MGS Flood software

Volume of Pond at Maximum Elevation = 2.165 ac-ft

(See attached file: TDA-C VOLUME 2.fld)

Assuming 20-ft wide modular vault @ 9-ft storage depth

Vault dimensions are approximately

2-ea @ 262'L x 20'W x 10'D

Different vault configurations possible.

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MGS FLOOD
PROJECT REPORT

Program Version: 2.2.5 Run Date: 02/28/2005 1:29 PM
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Input File Name: TDA-C FLOWRATES2.fld
Project Name : TDA-C VAULT REDUCTION
Analysis Title: **STEP 1** POST DEVELOPED FLOW RATE
Comments : CALC PEAK FLOW RATES FOR ON-SITE MITIGATION AREA ROUTED TO VAULT

Extended Timeseries Selected
Climatic Region Number: 11

Full Period of Record Available used for Routing
Precipitation Station : 960040 Puget East 40 in MAP 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** Watershed Definition **********
Number of Subbasins: 1

********** Subbasin Number: 1 **********
***Tributary to Node: 1
***Bypass to Node : None

	---------Area(Acres) ----------			
		------Developed-----		
	Predeveloped	To Node	Bypass Node	Include GW
Till Forest	0.000	0.000	0.000	No
Till Pasture	0.000	0.000	0.000	No
Till Grass	0.000	0.000	0.000	No
Outwash Forest	0.000	0.000	0.000	No
Outwash Pasture	0.000	0.000	0.000	No
Outwash Grass	0.000	0.000	0.000	No
Wetland	0.000	0.000	0.000	No
Impervious	7.960	7.960	0.000	
SUBBASIN TOTAL	7.960	7.960	0.000	

*** Subbasin Connection Summary ***
Subbasin 1 ----------> Node 1

*** By-Pass Area Connection Summary ***
No By-Passed Areas in Watershed

********** Flow Frequency Data for Selected Recurrence Intervals **********

Tr (Years)	Subbasin 1 Runoff Predevelopment* Flow(cfs)	Subbasin 1 Runoff Postdevelopment* Flow(cfs)
6-Month	1.547	1.547
2-Year	2.027	2.027
5-Year	2.628	2.628
10-Year	3.079	3.079
25-Year	3.718	3.718
50-Year	4.247	4.247
100-Year	4.824	4.824
200-Year	5.455	5.455

* Recurrence Interval Computed Using Generalized Extreme Value Distribution

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MGS FLOOD
PROJECT REPORT

Program Version: 2.2.5 Run Date: 02/28/2005 1:37 PM
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Input File Name: TDA-C OFFSITE FLOWRATES 2.fld
Project Name : TDA-C VAULT REDUCTION
Analysis Title: **STEP 2** MAX OFFSITE AREA
Comments : CALC MAX OFFSITE AREA SUCH THAT Q100 IS LESS THAN 2.41-CFS

Extended Timeseries Selected
Climatic Region Number: 11

Full Period of Record Available used for Routing
Precipitation Station : 960040 Puget East 40 in MAP 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** Watershed Definition **********
Number of Subbasins: 1

********** Subbasin Number: 1 **********
***Tributary to Node: 1
***Bypass to Node : None

	---------Area(Acres) ----------			
		------Developed-----		
	Predeveloped	To Node	Bypass Node	Include GW
Till Forest	0.000	0.000	0.000	No
Till Pasture	0.000	0.000	0.000	No
Till Grass	0.000	0.000	0.000	No
Outwash Forest	0.000	0.000	0.000	No
Outwash Pasture	0.000	0.000	0.000	No
Outwash Grass	0.000	0.000	0.000	No
Wetland	0.000	0.000	0.000	No
Impervious	3.900	3.900	0.000	
SUBBASIN TOTAL	3.900	3.900	0.000	

*** Subbasin Connection Summary ***
Subbasin 1 ----------> Node 1

*** By-Pass Area Connection Summary ***
No By-Passed Areas in Watershed

********** Flow Frequency Data for Selected Recurrence Intervals **********

Tr (Years)	Subbasin 1 Runoff Predevelopment* Flow(cfs)	Subbasin 1 Runoff Postdevelopment* Flow(cfs)
6-Month	0.758	0.758
2-Year	0.993	0.993
5-Year	1.288	1.288
10-Year	1.509	1.509
25-Year	1.822	1.822
50-Year	2.081	2.081
100-Year	**2.363**	**2.363**
200-Year	2.673	2.673

* Recurrence Interval Computed Using Generalized Extreme Value Distribution

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MGS FLOOD
PROJECT REPORT

Program Version: 2.2.5 Run Date: 02/28/2005 2:57 PM
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Input File Name: TDA-C VOLUME 2.fld
Project Name : TDA-C VAULT REDUCTION
Analysis Title: **STEP 3** CALCULATE DETENTION VOLUME
Comments : DETENTION VAULT SIZING CALC USING OFFSITE IN-FLOW AREA OPTION

Extended Timeseries Selected
Climatic Region Number: 11

Full Period of Record Available used for Routing
Precipitation Station : 960040 Puget East 40 in MAP 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** Watershed Definition **********
Number of Subbasins: 1

********** Subbasin Number: 1 **********
***Tributary to Node: 1
***Bypass to Node : None

	---------Area(Acres) ----------			
		------Developed-----		
	Predeveloped	To Node	Bypass Node	Include GW
Till Forest	7.960	0.000	0.000	No
Till Pasture	0.000	0.000	0.000	No
Till Grass	0.000	0.000	0.000	No
Outwash Forest	0.000	0.000	0.000	No
Outwash Pasture	0.000	0.000	0.000	No
Outwash Grass	0.000	0.000	0.000	No
Wetland	0.000	0.000	0.000	No
Impervious	3.610	11.570	0.000	
SUBBASIN TOTAL	11.570	11.570	0.000	

*** Subbasin Connection Summary ***
Subbasin 1 ----------> Node 1

*** By-Pass Area Connection Summary ***
No By-Passed Areas in Watershed

Pond Inflow Node : 1
Pond Outflow Node: 99

********** Retention/Detention Facility Summary **********

Hydraulic Structures Add-in Routines Used
---------- Pond Geometry ----------

Prismatic Pond Option Used

Pond Floor Elevation : 100.00 ft
Riser Crest Elevation : 109.00 ft
Maximum Pond Elevation : 109.50 ft
Maximum Storage Depth : 9.00 ft
Pond Bottom Length : 498.1 ft
Pond Bottom Width : 19.9 ft
Side Slope : 0.00 ft/ft
Infiltration Rate : 0.00 in/hr
Pond Bottom Area : 9926. sq-ft
Area at Riser Crest El : 9926. sq-ft
: 0.228 acres
Volume at Riser Crest : 89330. cu-ft
: **2.051 ac-ft**
Area at Max Elevation : 9926. sq-ft
: 0.228 acres
Volume at Max Elevation: 94293. cu-ft
: **2.165 ac-ft**

---------- Riser Geometry ----------
Riser Structure Type : Circular
Riser Diameter : 18.00 in
Common Length : 0.028 ft
Riser Crest Elevation : 109.00 ft

---------- Hydraulic Structure Geometry ----------

Number of Devices: 3

--- Device Number 1 ---
Device Type : Circular Orifice
Invert Elevation : 100.00 ft
Diameter : 3.09 in
Orientation : Horizontal
Elbow : No

--- Device Number 2 ---
Device Type : Vertical Rectangular Orifice
Invert Elevation : 103.84 ft
Length : 0.3 in
Height : 61.9 in
Orientation : Vertical
Elbow : No

********** Flow Frequency Data for Selected Recurrence Intervals **********

Tr (Years)	Subbasin 1 Runoff Predevelopment* Flow(cfs)	Subbasin 1 Runoff Postdevelopment* Flow(cfs)	Pond Outflow Node Postdevelopment** Flow(cfs)
6-Month	0.757	2.248	
2-Year	1.017	2.947	0.582
5-Year	1.343	3.820	0.860
10-Year	1.588	4.476	1.024
25-Year	1.938	5.404	1.484
50-Year	2.228	6.173	1.537
100-Year	2.546	7.012	1.779
200-Year	2.895	7.929	2.699

* Recurrence Interval Computed Using Generalized Extreme Value Distribution
** Computed Using Gringorten Plotting Position

**** Flow Duration Performance According to Dept. of Ecology Criteria ****
Excursion at Predeveloped ½Q2 (Must be Less Than 0%): -11.5% PASS
Maximum Excursion from ½Q2 to Q2 (Must be Less Than 0%): -10.7% PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%): 6.5% PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%): 5.9% PASS

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* POND MEETS ALL DURATION DESIGN CRITERIA: PASS
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********** Water Quality Facility Data **********

Basic Wet Pond Volume (91% Exceedance): 50114. cu-ft
Computed Large Wet Pond Volume, 1.5*Basic Volume: 75171. cu-ft
2-Year Stormwater Pond Discharge Rate: 0.582 cfs

15-Minute Timestep, Water Quality Treatment Design Discharge
Discharge Rates Computed for Node: 1
On-line Design Discharge Rate (91% Exceedance): 0.00 cfs
Off-line Design Discharge Rate (91% Exceedance): 0.00 cfs

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